PB86-174067

# Highlights in U.S. Technological Development in Landfilling of Sludge

(U.S.) Environmental Protection Agency
Cincinnati, OH

Mar 86

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-174067

EPA/600/D-86/056
March 1986

# HIGHLIGHTS IN U. S. TECHNOLOGICAL DEVELOPMENT IN LANDFILLING OF SLUDGE

by

J. B. Farrell
Wastewater Research Division
Water Engineering Research Laboratory
Cincinnati, Ohio 45268

WATER ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA/600/D-86/056 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Highlights in U. S. Technological Development in Landfilling of Sludge | March 1986 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
| J. B. Farrell | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
| Wastewater Research Division<br>Water Engineering Research Laboratory<br>26 West St. Clair Street<br>Cincinnati, OH 45268 | 11. CONTRACT/GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
| Water Engineering Research Laboratory, Cin., OH<br>Office of Research and Development<br>U.S. Environmental Protection Agency<br>Cincinnati, OH 45268 | 14. SPONSORING AGENCY CODE<br>EPA/600/14 |

15. SUPPLEMENTARY NOTES

Author: J. B. Farrell (513) 569-7645 FTS 8-684-7645

16. ABSTRACT

This presentation reviews practice and important developments in the technology of disposition of municipal wastewater sludge in sludge and sludge-refuse landfills. EPA's regulations of landfilling and this impact on the technology are presented. The increase in use of predictive models in the regulation and design of landfills is cited. New knowledge and developments in the technology of sludge and sludge-refuse landfills is presented. Results of a research investigation that demonstrates the large net reduction in leachate contamination that occurs when sludge and refuse are disposed together are described in summary form. The recommendation is made that sludge and refuse be disposed together rather than to separate landfills in order to reduce total environmental impact.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| | | |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
|---|---|---|
| RELEASE TO PUBLIC | Unclassified | 31 |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |
| | Unclassified | |

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

# HIGHLIGHTS IN U. S. TECHNOLOGICAL DEVELOPMENT IN LANDFILLING OF SLUDGE

by

J. B. Farrell

## Introduction

Approximately 25 percent of the wastewater treatment plant sludge generated in the United States is landfilled (1). Sludge is most commonly co-disposed with refuse but substantial amounts are disposed in landfills containing only sludge. The process design of both types of landfills is thoroughly explained in an EPA Design Manual (2). The Table of Contents of this manual is presented in Table 1 to illustrate the extent of coverage of the subject in this manual.

Landfilling of sludge, although important to operators of wastewater treatment plants, is a small part of the total landfilling problem in the United States. Most of the domestic and commercial refuse generated in the United States is landfilled. Great quantities of industrial wastes, including wastes from chemical and pesticide manufacture have been landfilled. In past years, much of this disposal was poorly conducted generally at sites not far from the cities. Now our cities have expanded and are frequently surrounded by small suburban communities. Old dumping areas are often within city limits and are frequently close to homes. Abandoned refuse and industrial waste landfills have frequently contaminated groundwater making it unsuitable for drinking and in some cases so dangerous that contact with it or inhaling released vapors can threaten health. The Love Canal dumping area in New York State is an extreme example. At this site, toxic chemicals migrated from the dump site, in some cases entering basements of homes. Homes had to be abandoned and portions of the area permanently sealed off. The public has reacted with alarm to these hidden dangers. All landfilling has become suspect. Federal, state, and local communities have responded with laws, regulations, and restrictions that are needed, but may be overly restrictive for wastes that are not hazardous. Although the climate is now unfavorable for landfill disposal of sludge, the overall result of our awareness of the potential hazards from irresponsible landfilling is salutory. Regulations require that hazardous wastes be sent to secure landfills or destroyed by chemical action or incineration. Refuse and/or sludge landfills should no longer be contaminated with such substances. The attention to the problem has greatly expanded research interest into landfill-related problems. Much has been learned about leachate migration and ways to control it although much remains to be learned.

This presentation is concerned only with sludge and sludge-refuse landfills. Developments related to hazardous waste disposal are excluded except when relevant to sludge and sludge-refuse landfilling. It presents the federal regulations controlling sludge landfilling and reviews important developments and trends in disposal of sludge in landfills in the United States in recent years.

2/27/86

## Regulation of Sludge Disposal to Landfills

The regulation of sludge disposed to landfills is contained in 40 CFR, Part 257, "Criteria for Classification of Solid Waste Disposal Facilities and Practices" (3). The criteria do not distinguish between municipal refuse and sewage sludge; the same requirements apply to landfilling of both types of waste. The criteria are for use in determining which facilities and practices pose a reasonable probability of adverse effects on health and the environment. Facilities failing to satisfy the criteria are classified as open dumps and are prohibited. The document also provides guidance for utilization or disposal of sludge on land. The major requirements of the criteria relevant to landfills are briefly summarized below:

Floodplain (257.3-1). Facilities or practices shall not restrict the flow of the base flood (the 100 year flood), reduce the storage capacities of the floodplain, or result in washout of solid waste.

Endangered Species (257.3-2). Facilities or practices shall not facilitate reduction in numbers of an endangered species or destroy or adversely affect habitat.

Surface Water (257.3-3). A facility shall not cause a discharge of pollutants into waters of the United States that violates the requirements of the National Pollutant Discharge Elimination System (i.e., does not exceed the limits stated in the required NPDES permit).

Ground Water (257.3-4). A facility or practice shall not contaminate an underground water source beyond the solid waste disposal site boundary or beyond an alternative boundary (Alternative boundary is decided by a court after consideration of relevant factors such as dilution by the aquifer, volume and characteristics of leachate, flow of underground water, proximity and withdrawal rate of users, availabilty of alternative water supplies, existing quality of the water, public health, safety and welfare. The state may establish an alternative boundary only if it finds that ground water that may be used for human consumption would not be contaminated). Appendix I of the document gives maximum contaminant levels for inorganic and organic chemicals, microbiological species, and radioactivity.

Disease (257.3-6). The facility or practice must minimize the on-site population of disease vectors through periodic application of cover material or other techniques appropriate to protect the public health.

Air (257.3-7). The facility shall not engage in open burning of waste.

Safety (257.3-8). Explosive gases shall not exceed 25% of the lower explosive limit or be greater than the lower explosive limit at the property boundary. The facility shall not pose a hazard of fire, shall not represent a hazard to aircraft (from birds attracted to waste), shall not allow uncontrolled access.

The regulations are general in nature. Nevertheless, they exert effective control over landfilling. For example, the requirement that groundwater not be contaminated (257.3-4) clearly implies a monitoring

requirement. Similarly, the safety requirement (257.3-8) that the lower explosive limit not be exceeded at the plant boundary implies that the ground be monitored to verify that methane is not migrating through the soil in hazardous concentrations. Most states have developed regulations which are generally more specific, and which can be more restrictive (but not less restrictive) than the federal regulations. One state, New Jersey, has banned sludge in landfills.

Regulation has greatly improved the technology of sludge landfills and has led to a search for methods to evaluate landfill performance, and the development of landfilling techniques that minimize pollution.

## Developments in Landfilling Technology

Predictive Models. The great concern and extensive study relating to hazardous waste landfilling is bringing about new knowledge that is useful in site location, design and operation of any kind of landfill. One example of this development is the intensive work on development of predictive models. One such model that is seeing substantial use in the United States is the HELP Model (Hydrologic Evaluation of Landfill Performance) (4). This model was developed by staff at the U. S. Army Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi, for the U.S. EPA. The authors describe the objective and capability of the model as follows:

> "The HELP program was developed to facilitate rapid economical estimation of the amounts of surface runoff, subsurface drainage, and leachate that may be expected to result from the operation of a wide variety of possible landfill designs. The program models the effects of hydrologic processes including precipitation, surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage using a quasi-two-dimensional approach."

Volume I of Reference 4 discusses input/output options in detail, and instructions are given for running the program on the National Computer Center IBM Computer System. Volume II presents the theories and assumptions upon which the HELP model is based, the solution techniques employed, and the internal logic of the computer program. Use of models such as the HELP model has vastly simplified the task of regulation. Such models are user-friendly, and a regulatory official with limited field experience with landfilling can do a creditable job of assessing a proposed landfill site. Designers are made aware of the complexity of the subject and of need for adequate data to develop a satisfactory design. The model provides a means for rapidly assessing suggested design improvements. However, it is no substitute for creative and informed specialists in landfill design.

Sludge-refuse Landfilling. The general upgrading of the practice of solid waste landfilling (better site selection, use of impervious layers of soil or synthetic membrane sheets to prevent leachate contaminants from reaching groundwater, collection of leachate for treatment) has upgraded the performance of sludge-solid waste landfills. There has been no marked improvement in the practice of incorporating sludge. Sludge is mixed with refuse at the working face of the landfill. Use of too high a proportion of sludge to refuse should be avoided. It creates a hazardous working environment and causes excessive production

of leachate. Research by the Los Angeles County Sanitation Districts, which has been summarized by Lu et al. (5), shows definitive information on the amount of sludge that can be incorporated into refuse. Figure 1 shows the proportion of sludge to refuse at which leachate will be generated. As expected, this ratio is lower for deep landfills when the high pressure on the sludge-refuse mixture causes the water in the sludge to migrate to lower pressure areas. These data apply to typical U. S. refuse which contains a higher percentage of paper products, which are very absorbent, than the refuse from other countries, where more plastic bags are used for packaging. Other figures as presented by Lu et al. (5) for use in predicting moisture release as a function of sludge-to-refuse ratio and sludge moisture content are difficult to use. A slight rearrangement in variables presented in Figure 2 makes the data more useful. The use of this figure is explained in Table 2. By using this figure, leachate quantity per kilogram of sludge added to the landfill can be predicted provided the weight ratio of wet sludge to refuse and the moisture content of the sludge are known. It must be pointed out that biodegradation that eventually occurs as anaerobic processes take place within the landfill will produce more leachate than predicted by this figure.

Sludge Landfilling. As noted in Reference 1, most sludge landfills consist of a series of trenches into which dewatered sludge is deposited and covered with soil. Sludge landfill trenches may be wide (3 to 15 m) or narrow (1 to 3 m). The use of narrow trenches has grown considerably despite high area requirements. Reference 2 indicates that capacity is about 2800 $m^3$ of wet sludge cake/ha. This method has found much more acceptance than other forms of landfilling in the vicinity of Washington, D. C., and in other areas where siting of a conventional refuse landfill or a wide-trench sludge landfill would meet community resistance. One of the very important advantages of narrow trench landfilling is that the time that the sludge is uncovered can be reduced to minutes with subsequent minimal likelihood of unpleasant odors. Figure 3 illustrates an efficient operation carried out in Montgomery County near Washington, D.C. Other advantages of this method of application are its low impact on the environment and the likelihood that the land can be used for agricultural purposes after 4 to 5 years, possibly even for food chain crops. Probably the most significant contaminant from sludge landfills is nitrogen leaching to groundwater. The relatively low loading of sludge per hectare reduces this likelihood. Also, the spaces between trenches provides aerobic zones in the soil adjacent to anaerobic zones. Under these conditions, a substantial amount of denitrification of ammonia to harmless nitrogen gas occurs, reducing the potential impact on groundwater. Procedures used are described in two EPA reports (6,7). Sikora and coworkers (8,9,10) describe fate of metals and nitrogen in sludge after entrenchment into a sandy soil at an experimental site. Metal movement was slight but ammonium movement was substantial. Wells within the site frequently showed concentrations of $NH_4$ above 10 mg/L (10) but wells on the perimeter of the site never exceeded this level. Monitoring at a full-scale site (11) where limed sludge was disposed showed similar effects. Effects diminished to a much reduced level after 4 years. At this site, investigation showed regrowth of coliforms within the sludge as time progressed (pH of limed sludge decreases with time) but no regrowth of salmonella. Growth of fecal coliform to low levels occurred below the sludge bed but diminished to below detectable levels after 37 months.

Use of wider trench landfilling is described in References 1 and 2 and in the attached paper by Beatty.

Minimizing Leachate and Maximizing Gas Production. The dearth of information on the effects of sludge addition to a refuse landfill on the quality and quantity of leachate motivated EPA's Water Engineering Research Laboratory to commence a study of the effects of sludge addition on the composition of leachate. The investigations were conducted using large test cells (Figure 4) installed in EPA's Test and Evaluation Facility in Cincinnati. Leaching and gas production were investigated for simulated sludge-refuse and sludge landfills. The detailed experimental design is presented in Table 3. Variables investigated for the sludge-refuse case were sludge type (raw limed vs. anaerobically digested), proportion of sludge added (0, 10, 20, and 30 percent by weight of wet sludge), and water infiltration rate (0.5 L/kg-yr and 1.0 L/kg-yr). For the sludge case, variables were sludge type (raw limed vs. anaerobically digested), and sludge depth (0.6 m, 1.8 m) at a single water infiltration rate (0.5 L/kg-yr). This investigation is continuing and has not been reported in the literature as yet. Results are sufficiently interesting to merit a brief presentation of major findings at this time.

The most striking effect noted in the experiment was the great effect on the COD (chemical oxygen demand) of the leachate caused by sludge addition. This effect is shown for limed sludge and refuse in Figure 5 and for anaerobically digested sludge and refuse in Figure 6. The addition of sludge produces a remarkable reduction in COD for both kinds of sludge. The effect is noticed earliest with the anaerobically digested sludge and 4-6 months later for the limed sludge. The effect of percentage of sludge between 10 and 30% is not clear. More sludge seemed to help reduction occur earlier for limed sludge, but the reverse for the anaerobically digested sludge. After about 2-1/2 years, the COD of the leachate from the refuse cell fell to the same level as for the sludge-refuse cells, indicating that methanation was finally taking place--the dissolved components in the leachate (primarily volatile acids) were finally being converted to methane and carbon dioxide.

Leachate COD versus time is presented in Figure 7 for the sludge cells. The COD for the lime-treated sludge (LT) is much higher than for the anaerobically digested sludge (AD). The LT cell leachate appears to be falling to lower levels after three years of operation. It is interesting to note that the leachate COD's from the AD cells are not as low as from the AD-refuse cells (Figure 6).

The results of these experiments indicate that COD of leachates from refuse landfills could be greatly reduced by incorporation of sludge in the landfill. This was true for both lime-treated sludge and anaerobically digested sludge. Leachate from lime-treated sludge disposed alone was substantial--it would be better if it were disposed with refuse. Disposal of anaerobically digested sludge alone had little environmental impact, but it would be better to dispose of it with refuse in order to reduce the environmental impact of the refuse landfill.

## REFERENCES


(1) U.S. EPA, "Environmental Regulations and Technology: Use and Disposal of Municipal Wastewater Sludge," EPA-625/10-84-003, Sept. 1984.

(2) U.S. EPA, "Process Design Manual: Municipal Sludge Landfills," EPA-625/1-78-010, Oct. 1978.

(3) Code of Federal Regulations, 40 CFR, Part 257, "Criteria for Classification of Solid Waste Disposal Facilities and Practices," from any CFR pub. after Sept. 1981.

(4) Schroeder, P. R., Morgan, J. M., Walski, T. M., and Gibson, A. C., "The Hydrologic Evaluation of Landfill Performance (HELP) Model, Vol. I, Users Guide for Version 1, EPA/530-SW-84-009 Vol. II, Documentation for Version 1," EPA/530-SW-84-010

(5) Lu, J. C. S., Eichenberger, B., and Stearns, R. J., "Production and Management of Leachate from Landfills: Summary and Assessment," EPA-600/2-84-092 (1984).

(6) Walker, J. M., Burge, W. D., Chaney, R. L., Epstein, E., and Menzies, J. D., "Trench Incorporation of Sewage Sludge in Marginal Agricultural Land," EPA-600/2-75-034 (1975).

(7) Walker, J. M., Ely, L., Hundemann, P., Frankos, N., and Kamuski, A., "Sewage Sludge Entrenchment System for Use by Small Municipalities," EPA-600/2-78-018 (1978).

(8) Sikora, L. J., Frankos, N. H., Murray, C. M., and Walker, J. M., "Effects of Trenching Undigested Lime-stabilized Sludge," Jour. Wat. Poll. Contr. Fed., 51, 1841-1849 (July 1979).

(9) Sikora, L. J., Frankos, N. H., Murray, C. M., and Walker, J. M., "Trenching of Digested Sludge," Jour. Envir. Eng. Div., ASCE, 106, No. EE2, 351-361 (April 1980).

(10) Sikora, L. J., Murray, C. M., Frankos, N. H., and Walker, J. M., "Water Quality at a Sludge Entrenchment Site," Ground Water, 16, No. 2, March-April 1978.

(11) Sikora, L. J., Burge, W. D., and Jones, J. E., "Monitoring of a Municipal Sludge Entrenchment Site," Jour. Envir. Qual., 11, No. 2, 321-326 (1982).

## ADDENDUM*

Guidance recently issued by the U.S. EPA related to hazardous waste disposal in landfills may be useful to operators and designers of landfills for municipal refuse and sludge. Subjects and references are noted below:

a. improved design for landfill liners and covers (1,2)
b. guidance on assuring quality of construction (3)
c. restrictions on types of wastes that can be placed in landfills (4)
d. regulations concerning closure and care of completed landfills (5)

## REFERENCES


(1) Code of Federal Regulations, 40 CFR, Part 264, "Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities," revised as of July 1, 1985.

(2) U. S. Environmental Protection Agency. "Minimum Technology Guidance Document on Double Liner Systems for Landfills and Surface Impoundments--Design, Construction, and Operation" (Draft), EPA/530-SW-014, Washington, D.C., 1985.

(3) U. S. Environmental Protection Agency. "Construction Quality Assurance for Hazardous Waste Land Disposal Facilities--Public Comment Draft," EPA/530-SW-021, Cincinnati, Ohio, 1985.

(4) U. S. Environmental Protection Agency, Hazardous Waste Management System: Land Disposal Restrictions," Federal Register, Tuesday, January 14, 1986, pages 1602-1766.

(5) U. S. Environmnental Protection Agency. "Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," (Closure and Post-Closure Care Requirements), Federal Register, Tuesday, March 19, 1985, pages 11068-11097.


---

* This Addendum has been provided by Mr. Michael Roulier, Hazardous Waste Engineering Research Laboratory, U.S. EPA, Cincinnati, Ohio.

TABLE 1

Contents of EPA's "Process Design Manual for Municipal Sludge Landfills"

| Chapter | | Pages |
|---|---|---|
| 1. | INTRODUCTION<br><br>Sludge Disposal Alternatives; Sludge Landfills and Solid Waste Disposal Facility Classification Criteria; Objectives, Scope, and Use of Manual; References. | 6 |
| 2. | PUBLIC PARTICIPATION PROGRAM<br><br>Introduction; Objectives of a Public Participation Program; Advantages and Disadvantages of a PPP; Participants, Design and Timing of PPP; Potential Areas of Public Concern; References. | 12 |
| 3. | SLUDGE CHARACTERISTICS AND LANDFILLING METHODS<br><br>Purpose and Scope; Sludge Sources, Treatment and Characteristics; Suitability of Sludge for Landfilling; Landfilling Methods; References. | 32 |
| 4. | SITE SELECTION<br><br>Purpose and Scope; Site Considerations; Site Selection Methodology; Example of Methodology; References. | 28 |
| 5. | DESIGN<br><br>Purpose and Scope; Regulations and Permits; Design Methodology and Data Compilation; Selection of Landfilling Method; Sludge-Only Trench Designs: Sludge-Only Area Fill Design; Codisposal Designs; Environmental Safeguards; Storm Water Management; Access Roads; Other Design Features; References. | 48 |
| 6. | OPERATION<br><br>Purpose and Scope; Method-Specific Operational Procedures; General Operational Procedures; Equipment and Personnel; Reference. | 32 |

TABLE 1 (Continued)


| Chapter | | Pages |
|---|---|---|
| 7. | MONITORING | |
| | Introduction; Groundwater Monitoring; Surface Water Monitoring; Gas Monitoring; References. | 17 |
| 8. | COMPLETED SITE | |
| | Introduction; Procedures for Site Closure; Characteristics of Completed Site; Completed Site Use; References. | 8 |
| 9. | MANAGEMENT AND COSTS | |
| | Introduction; Management Responsibility; Equipment Management and Documentation; Personnel Management and Recordkeeping; General Management and Recordkeeping; Cost Recordkeeping; Financing; Typical Costs; References. | 29 |
| 10. | DESIGN EXAMPLES | |
| | Introduction; Three Detailed Design Examples | 32 |
| 11. | CASE STUDIES | |
| | Introduction; Case Study Summaries: Montgomery County, Maryland; Waukegan, Illinois; Colorado Springs, Colorado; Denver, Colorado; Lorton, Virginia. | 64 |

## TABLE 2

### ILLUSTRATION OF THE USE OF FIGURE 2 TO PREDICT LEACHATE

**Problem** Compare leachate quantity per kg of dry sludge solids at the base of a 100 m deep landfill, at the 30 m depth, and at the 7.5 m depth.

**Given:** Ratio of wet sludge to refuse is 1 kg/kg.*
Sludge contains 20% solids (wet basis).

**Solution:** Convert ratio of wet sludge to refuse to dry basis.

$$1.0 \times 0.20 = 0.20 \text{ kg dss}^{**}/\text{kg refuse.}$$

Convert sludge solids content to kg water/kg dss.

$$\frac{1.0 - 0.20}{0.20} = 4.0 \text{ kg water/kg dss.}$$

Locate the point 0.20 kg dss/kg refuse, 4.0 kg dss/kg water on Figure 2. Proceed vertically downward (water leaves the sludge refuse mixture under pressure, but the kg dss to kg refuse ratio remains unchanged).

| Depth | Initial Moisture (kg water/kg dss) | Moisture at non-leaching ratio (kg water/kg dss) | Moisture released (kg water/kg dss) |
|---|---|---|---|
| 7.5 | 4.0 | 3.5 | 0.5 |
| 30 | 4.0 | 1.5 | 2.5 |
| 100 | 4.0 | 0.6 | 3.4 |

* This calculation neglects the moisture content in the refuse.

** dss = dry sludge solids

## TABLE 3: PROGRAM DESIGN

| Test Cell | Sludge Type | Sludge Loading (%) | Priority Pollutant Spike | Infiltration Rate | Waste Height (m) |
|---|---|---|---|---|---|
| Codisposal and Refuse-Only: | | | | | |
| 1 | AD | 10 | -- | Low | 1.8 |
| 2 | LT | 10 | -- | Low | 1.8 |
| 3 | AD | 10 | -- | High | 1.8 |
| 4 | LT | 10 | -- | High | 1.8 |
| 5 | AD | 20 | -- | Low | 1.8 |
| 6 | LT | 20 | -- | Low | 1.8 |
| 7 | AD | 20 | -- | High | 1.8 |
| 8 | LT | 20 | -- | High | 1.8 |
| 9 | AD | 30 | -- | Low | 1.8 |
| 10 | LT | 30 | -- | Low | 1.8 |
| 11 | AD | 30 | -- | High | 1.8 |
| 12 | LT | 30 | -- | High | 1.8 |
| 13 | AD | 20 | Spiked | Low | 1.8 |
| 14 | LT | 20 | Spiked | Low | 1.8 |
| 15 | AD | 20 | Spiked | High | 1.8 |
| 16 | LT | 20 | Spiked | High | 1.8 |
| 17 | -- | 0 | -- | Low | 1.8 |
| 18 | -- | 0 | -- | High | 1.8 |
| 19 | -- | 0 | -- | Low | 1.8 |
| 20 | -- | 0 | -- | High | 1.8 |
| Sludge-Only: | | | | | |
| 21 | AD | 100 | -- | Low | 0.6 |
| 22 | LT | 100 | -- | Low | 0.6 |
| 23 | AD | 100 | -- | Low | 1.8 |
| 24 | LT | 100 | -- | Low | 1.8 |
| 25 | AD | 100 | Spiked | Low | 0.6 |
| 26 | LT | 100 | Spiked | Low | 0.6 |
| 27 | AD | 100 | Spiked | Low | 1.8 |
| 28 | LT | 100 | Spiked | Low | 1.8 |

AD = Anaerobically Digested Sludge (16 percent solids)
LT = Lime Treated Sludge (16 percent solids)
10, 20, etc. = Percent (%) sludge addition by wet weight of sludge/refuse mixture
Spiked = Received solvent-based spike containing twelve priority pollutants
Low = Receives an annual water infiltration rate of 0.500 liters per kilogram of cell waste (refuse and/or sludge) on a dry weight basis
High = Receives an annual water infiltration rate of 1.000 liters per kilogram of cell waste (refuse and/or sludge) on a dry weight basis

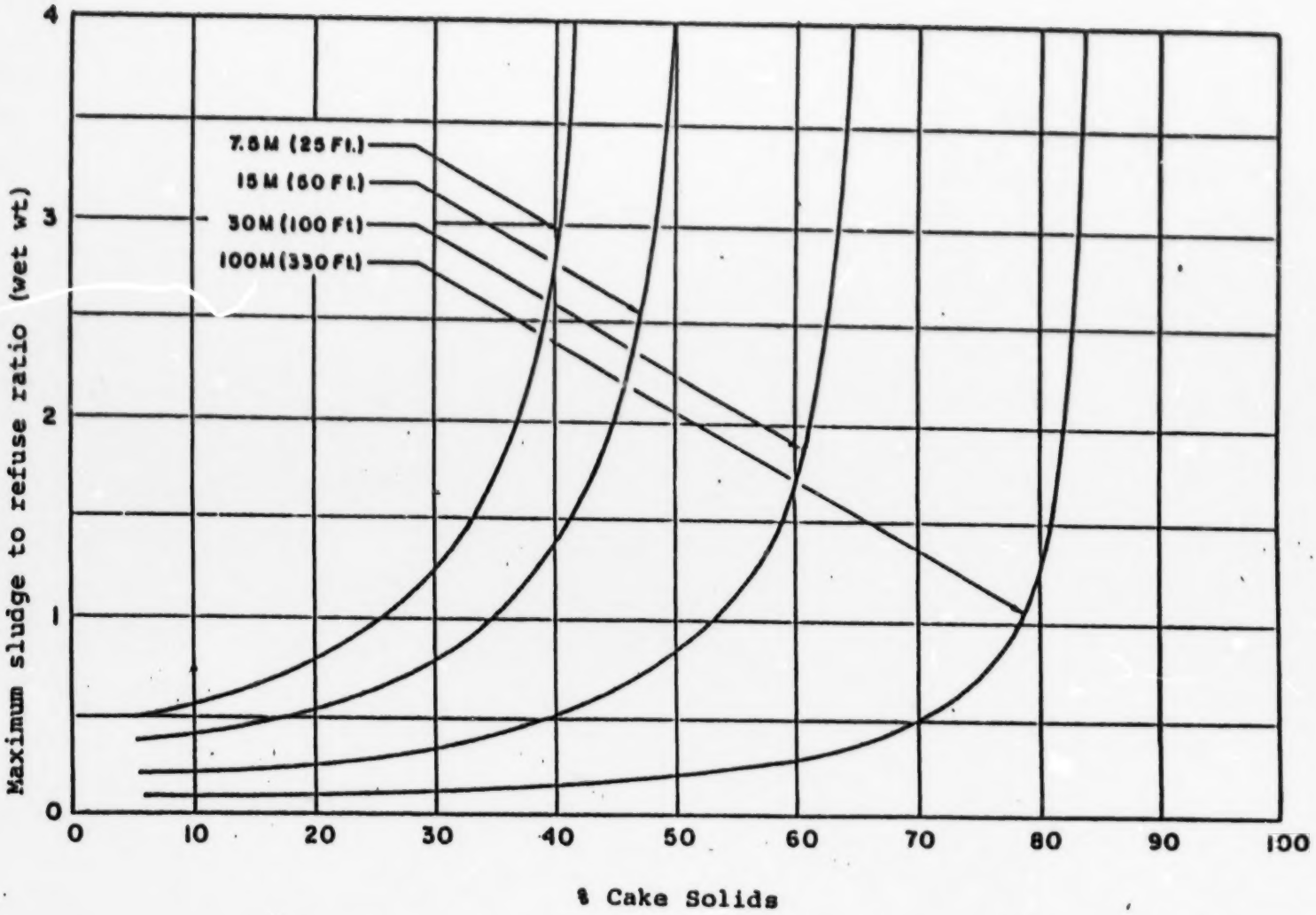



Figure 1: Maximum non-leaching sludge to refuse ratio (Parkhurst, 1978).

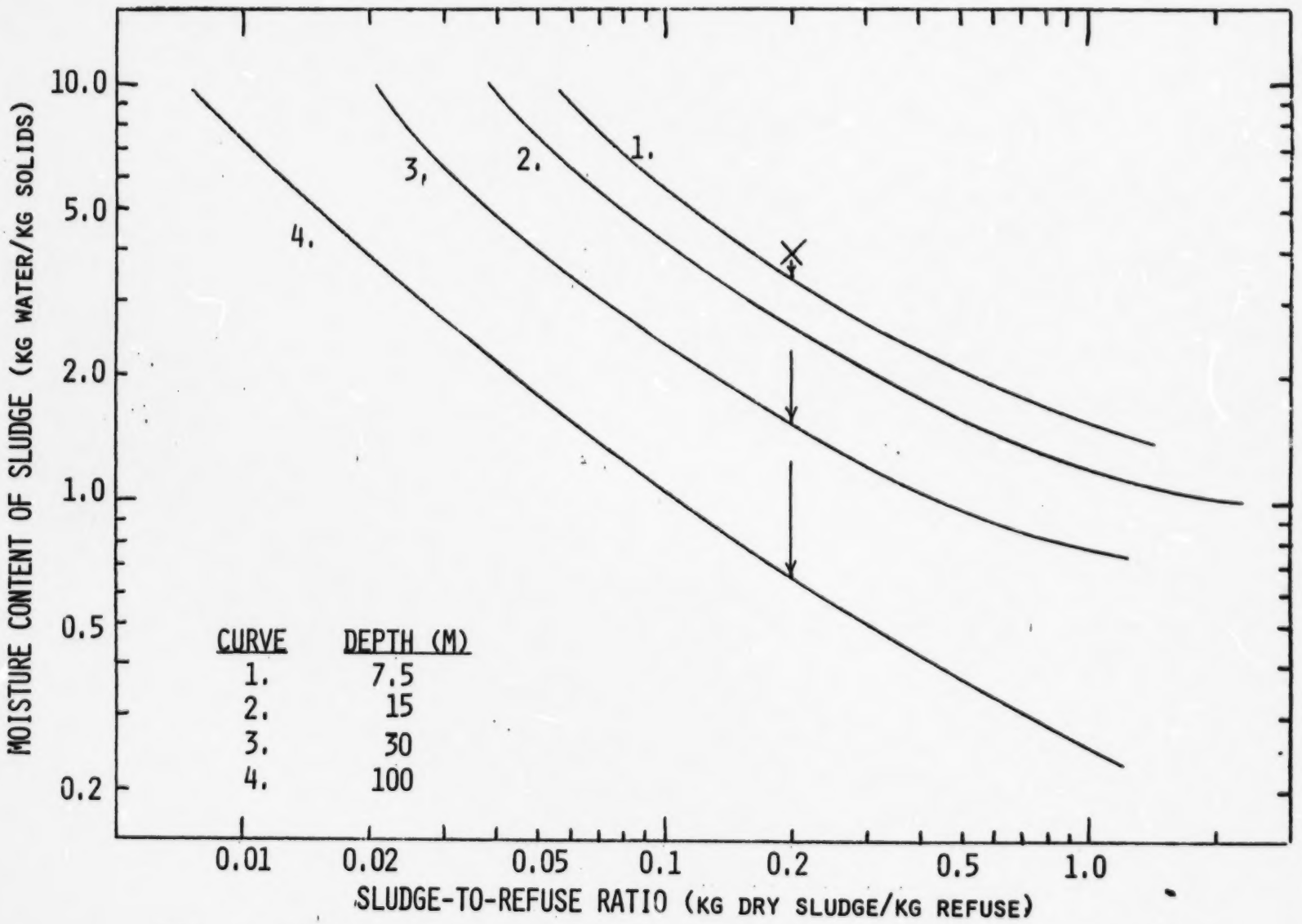



FIG. 2: MAXIMUM SLUDGE-TO-REFUSE RATIO THAT DOES NOT CAUSE LEACHING VERSUS SLUDGE MOISTURE CONTENT (ALTERNATIVE PLOT OF PARKHURST ET AL. DATA)

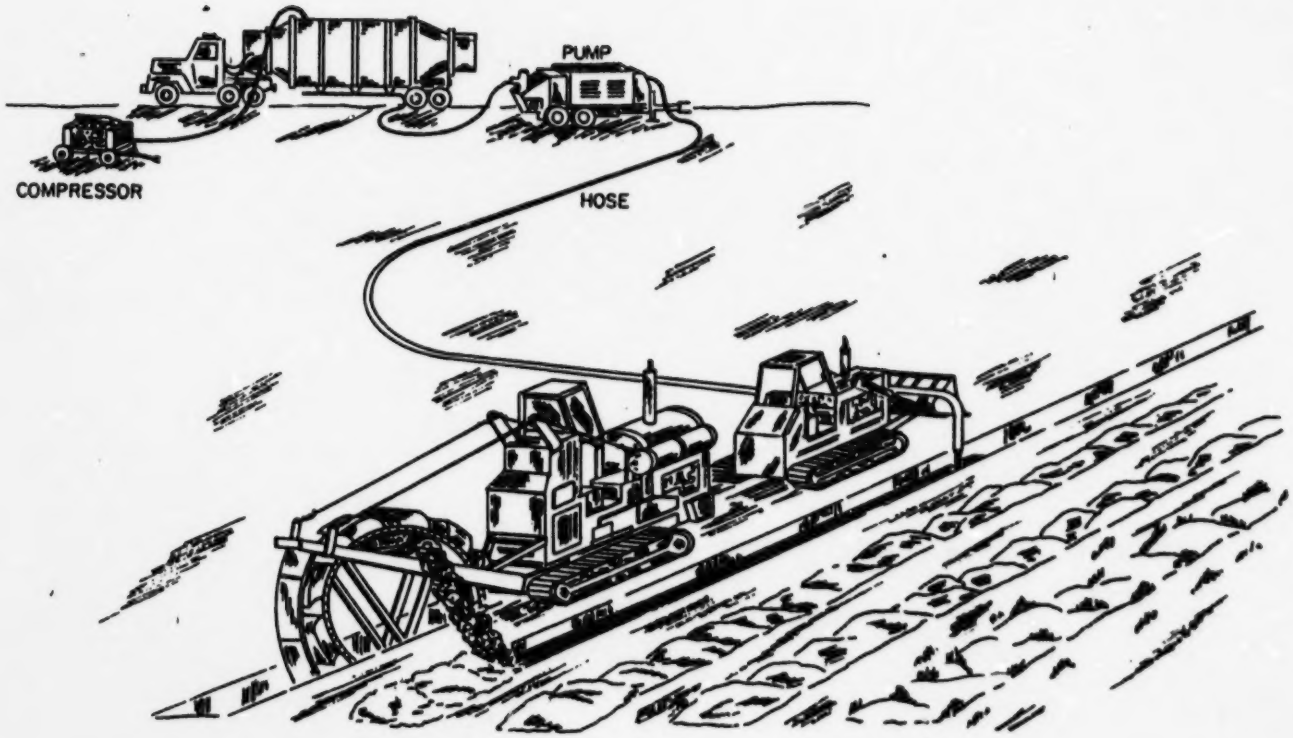



FIG. 3: NARROW TRENCH OPERATION, MONTGOMERY COUNTY, MARYLAND

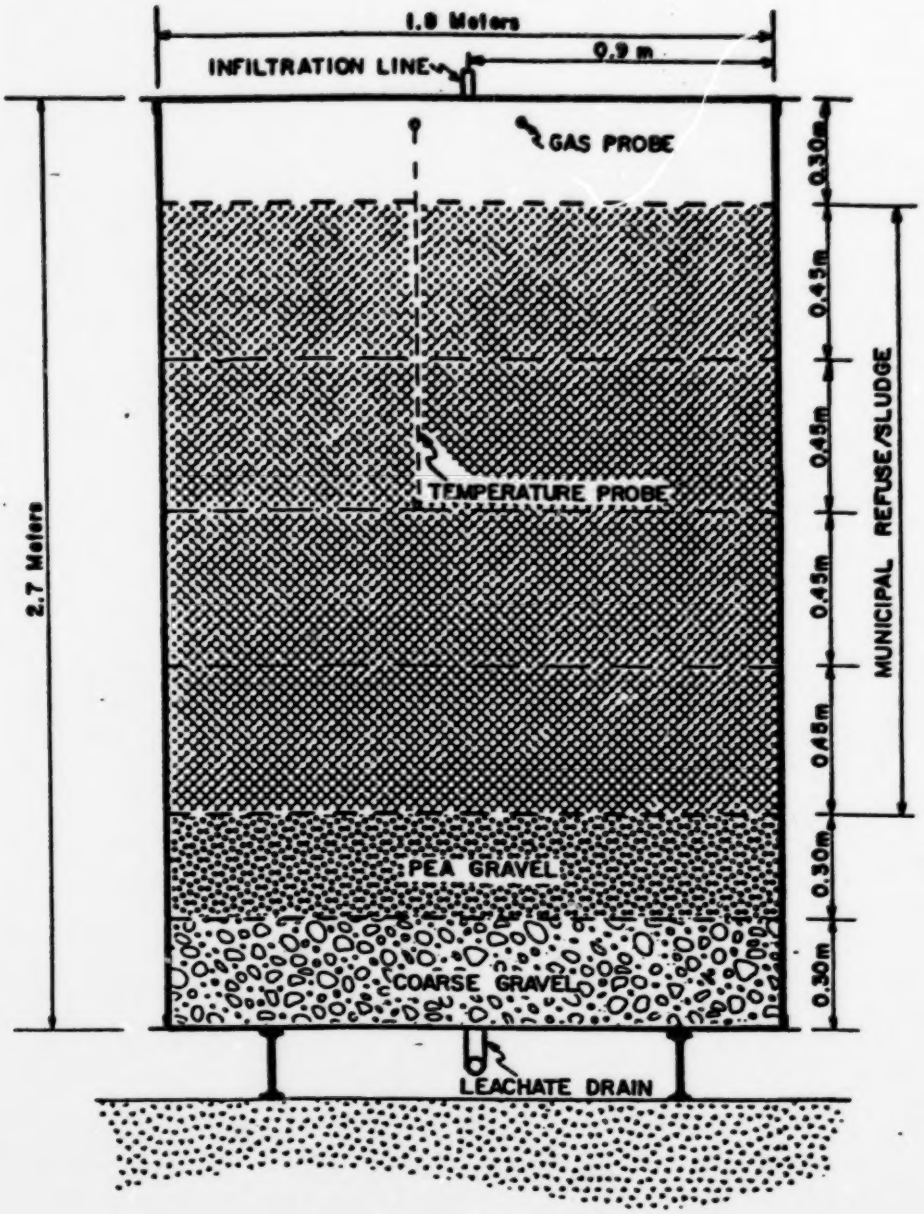



Figure 4. Cross-section of Sludge-Refuse Test Cell.

FIG. 5: Leachate COD vs Time
FOR LT/REFUSE CELLS

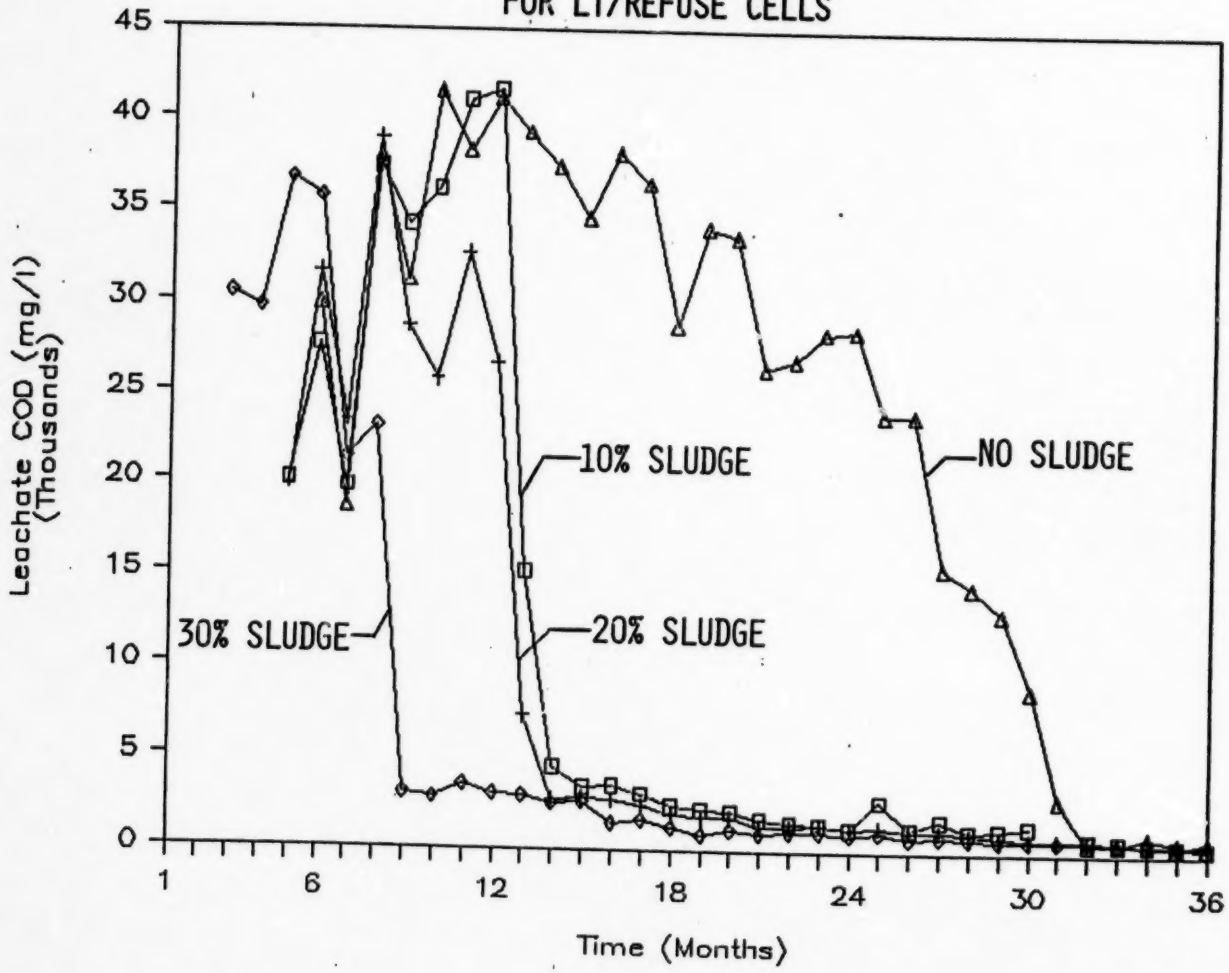


FIG. 6: Leachate COD vs Time
FOR AD/REFUSE CELLS

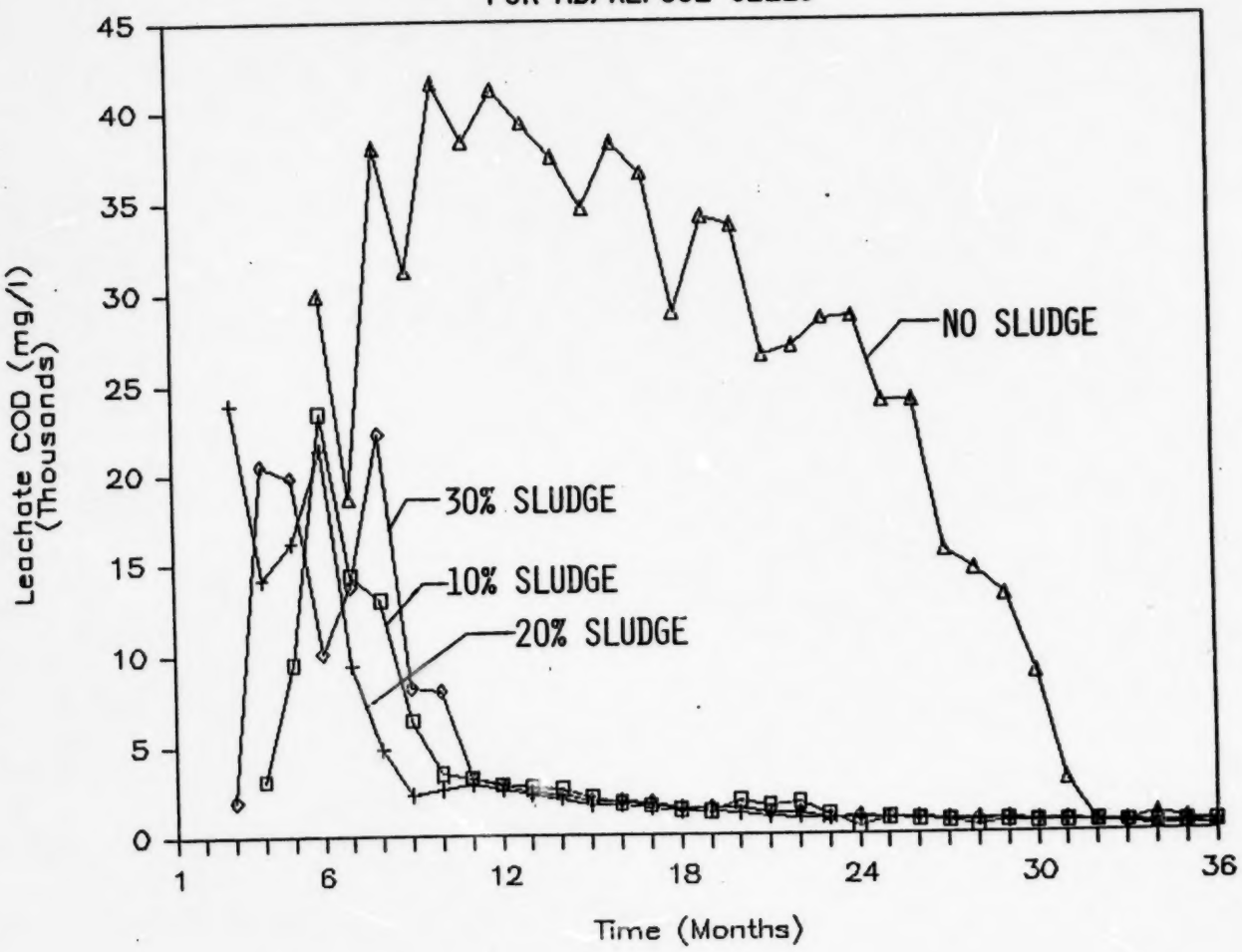
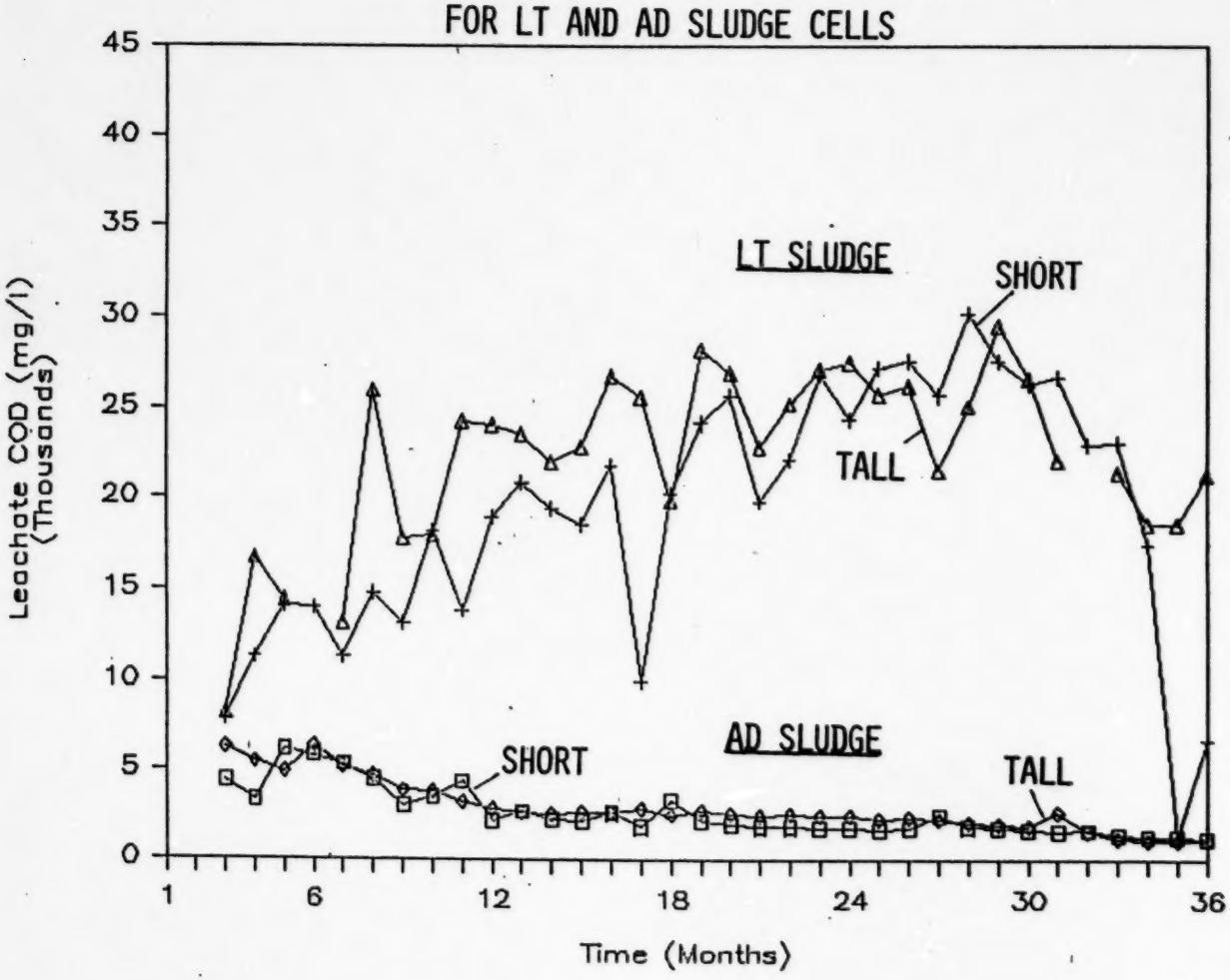


FIG. 7: Leachate COD vs Time



# SANITARY LANDFILLING OF SLUDGE AND/OR ASH*

by

C. D. Beatty

Camp, Dresser & McKee, Inc.

## Introduction

This presentation is limited to sanitary landfilling of wastewater sludges, including grease, grit and screenings, and incinerator ash. Sanitary landfilling can be defined as a method of disposing of solid wastes on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the solid waste to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary. This definition was developed for municipal solid wastes, and it does not include specifics with which the designer must be concerned, e.g. groundwater pollution. It does cite the most important objective of sanitary landfill design and use—protection of public health-and the definition can be applied to sludge landfill as well. The term sludge when used herein refers to dewatered sludge.

Before proceeding to discussion of some special considerations in sludge landfill site selection, design, and operation, it should be made clear that the requirements for sludge landfill depend upon the sludge to be handled. The sludge characteristics vary not only according to the characteristics of the wastewater being treated, but also according to the treatment provided, and, more importantly, to the processing of the sludge. In general terms, additional dewatering and stabilization steps (e.g., heat treatment or lime stabilization) make a sludge less difficult to landfill acceptably. Therefore, it appears reasonable to evaluate various sludge processing alternatives at the same time sludge landfilling is evaluated. Sludge landfilling is only one part of the disposal process; therefore, it should be evaluated along with related sludge handling and processing methods to assure an acceptable and cost effective disposal system. This point is made because the performance of landfills is very site related, and decisions regarding sludge processing, or lack of processing, should not be made until available landfill capability can be evaluated.

---

* Prepared for the U.S. EPA Sludge Treatment and Design Seminar, Boston, Mass., Sept. 14, 1977.

## Sludge Analysis and Potential Groundwater Contamination

Protection of groundwater is the most difficult problem in sludge landfill design. (Sludge sampling and analysis and the chemical composition of sewage sludge have been treated elsewhere in this series.) Three sludge components of particular concern are (1) pathogens, (2) nitrogen, and (3) heavy metals.

A stabilized sludge in a sanitary landfill environment generally provides unfavorable conditions for pathogenic organisms to propagate. However, the landfill designer should be aware of the pathogen threat to groundwater. Particular care is required where there are potable use wells nearby and disposal of an unstabilized sludge is required. Disposal in a very permeable soil, where there may be rapid flow of leachate to groundwater, would not be acceptable in this case.

Nitrates are limited in the EPA National Interim Primary Drinking Water Regulations (10 mg/l as N) because of health hazards, particularly in infants. Nitrogen in leachate from sludge landfills may be converted to the nitrate form ($NO_3^-$) during passage through unsaturated soil and subsequently enter the groundwater. Thus a sludge sanitary landfill should not be located where it could cause pollution of an existing drinking water supply or an aquifer which could be used for future drinking water supplies. Nitrates would not restrict use of the groundwater for most other potential (non-potable) uses.

Heavy metals are concentrated in sludges by wastewater treatment processes. At a low pH, the heavy metals of particular concern--lead, cadmium, zinc, copper, and nickel--are soluble and therefore are potential groundwater contaminants. Although the landfill may initially have a pH high enough to retain the heavy metals as precipitates, as decomposition takes place within the sludge, there will be a decrease of the pH and, as conditions become acidic, the heavy metals can be solubilized and can enter the groundwater via landfill leachate.

## Landfill Design, General

Sludge landfill design has many parallels with solid waste (refuse) landfill design. Control of vectors and odors (particularly) requires a daily application of earth cover. Surface water from areas adjacent to the fill should be channelized around and away from the sludge landfill area. Rainfall on the sludge fill area should be run off the site by a relatively impermeable cover placed at a slope great enough to prevent substantial infiltration without excessive erosion (about three percent). Placement of sludge should be in a confined area to minimize cover requirements. Leachate can be collected centrally and treated, or it can be treated by the soils under the landfill. Selection of the method of leachate treatment determines a basic design condition-whether the landfill will have a leachate collection system. Cover requirements vary substantially according to the dewatering

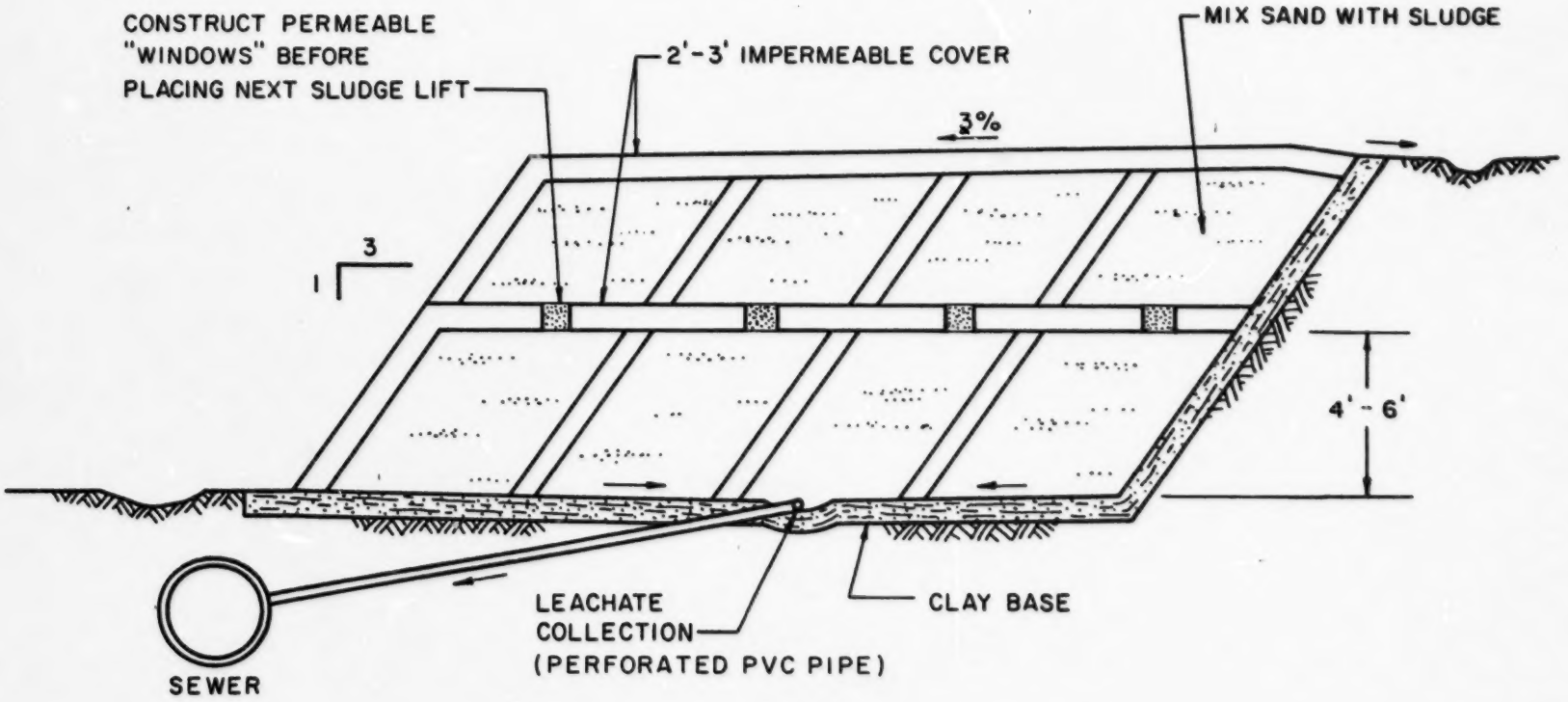
process and the percent solids in the sludge. A typical vacuum filtered sludge in the 20% to 25% solids range will require from one to two cubic yards of cover for each cubic yard of sludge placed in the landfill. A reasonable design assumption is that one and one-half cubic yards of cover will be required per cubic yard of sludge. The relatively large quantity of cover is required to provide stability to the fill in order that loaded vehicles can be driven on the fill to place the next lift. The quantity of cover material required for a very dry sludge cake, say 40% solids produced by a filter press, would certainly be less. A theoretical quantity of cover to provide a medium sized operation with six inches of daily cover would be about a half cubic yard of cover per cubic yard of sludge. It is not suggested that such a ratio is possible in actual practice, but a high solids sludge could be stable enough to permit use of much less than the 1.5:1 cover to sludge ratio cited for vacuum filtered sludge.

Landfill A: Leachate Collection and Centralized Treatment

Good leachate control can be provided by collection of leachate from the landfill and subsequent centralized treatment, either at the municipal wastewater treatment plant or at a plant designed specifically for treatment of the leachate. Figure 1 shows a cross section of Landfill A, which is based upon a CDM designed sludge landfill (with no solid wastes) for a particular New England Community. About forty cubic yards per day of the vacuum filtered sludge (22%-24% Solids) is placed in the landfill. The selected site is within a thousand feet of the municipal wastewater treatment plant and it is adjacent to an interceptor sewer. The base of the roughly five acre site is above the adjacent sewer, and it was prepared by removing a substantial quantity of various deposits including glacial till and sands. The base was further prepared by placing two feet of clay obtained from the plant site. A collection system consisting eight-inch perforated PVC pipe placed on crushed stone was installed with gravity flow to the adjacent sewer.

The actual landfilling operation proceeds by mixing sand with the sludge in a ratio of about one to two parts sand to two parts sludge. This operation is accomplished at the landfill site with a wheeled front end loader. The mixture is hauled to the landfill face where an area type landfill operation is conducted. The total lift height (depth of sludge plus cover) is about seven feet, and daily cover is placed at a ratio of about one part cover to two parts of the sludge/sand mixture. Thus, considering both sand and cover, sludge occupies between one-third and two-thirds of the total volume. The placing and cover operations are carried out by a tracked dozer. This operation has been attempted with a wheeled loader with little success. The sludge is not stable enough to support the more concentrated loads of the wheeled loader.

The first lift of the fill, constructed as described above, is sufficiently stable to support loaded trucks and little difficulty has been experienced in placing the second lift. Of course, in inclement weather a road would be required to support loaded trucks just as such a road would be required over any glacial till material. Roadway requirements can be minimized by maintaining the sand/sludge mixing area near the landfill entrance. With this procedure the mixed material can be hauled to the working face by loader instead of by truck.




(NOT TO SCALE)

FIGURE 1
LANDFILL "A"

Sludge tends to dewater after placement in a landfill. Experience with similar sludges without the sand mixture shows that a substantial depth of cover material is required to support truck traffic. This is caused by very poor drainage of the free water through the sludge. Therefore, the sand mixing step was introduced in an attempt to improve drainage within the sludge and increase operating stability. However, there appears to be no saving in cover material and sand, versus using cover material only.

Landfill A is not likely to pollute groundwater if the base material prevents leachate from passing through. Leachate returned to the municipal wastewater treatment plant could increase heavy metal loadings at the plant, and the plant sludge output in future years could have a higher heavy metal content than initially, even if the community wastewater is the same. However, the cover material placed on the lower lifts of the sludge landfill wil adsorb some heavy metals, and additional clay adsorption blankets could be placed with "new" sludge if this were to become a problem.

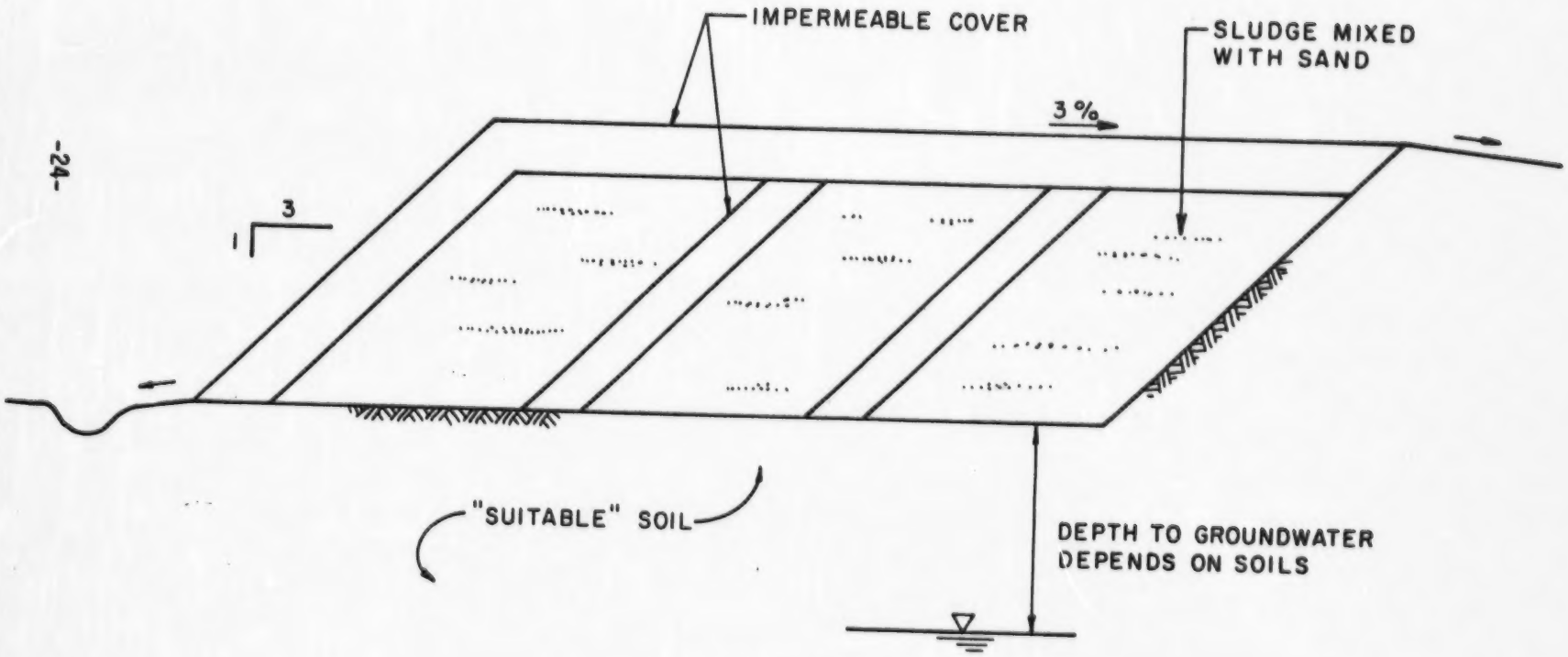
## Landfill B: Leachate Treatment by the Landfill Soil Base

Figure 2 shows a very simple cross section of landfill B. Landfill B has the same general operating requirements as Landfill A regarding mixing of sand to drain the sludge to increase stability of the fill. Cover requirements are similar and surface drainage is an identical problem. However, because there is no leachate collection system, important design decisions must be made on how to protect the groundwater from any leachate produced. The selection of a "suitable" soil to form the landfill base and the determination of the thickness of the base, which is the distance between the sludge and high groundwater, are critical decisions which are difficult, at least.

Although there have been some carefully documented positions on the feasibility of operating a "dry" landfill in the northeast, the conservative design engineer will assume that leachate will be produced and it will enter the groundwater. Therefore, that leachate must be treated before it reaches the groundwater or its impact must be estimated and judged acceptable. The only practical treatment system, without a leachate collection system, is by natural treatment in the soil. Important treatment parameters are soil particle size and quantity of soil. The depth to groundwater determines the quantity of soil the leachate may encounter. In general, most effective treatment is provided by fine organic soils over a low groundwater table.

## Landfill B, Base Design

An interesting note is provided here on a rather common experience in sanitary landfills. In an attempt to protect groundwater, a landfill may be placed on a thick clay base. This may be very successful in protecting the groundwater; however, in many cases, the fill reaches field saturation and leachate breaks out on the slopes of the fill, creating a surface water problem.




(NOT TO SCALE)

FIGURE 2
LANDFILL "B"

A granular material, e.g. a coarse sand, provides rapid flow and minimum attenuation of leachate pollutants. Therefore, it appears that a general design without leachate collection must tend toward use of soils between a clean sand and a organic clay.

A soil's ability to adsorb heavy metals is of particular interest in designing a sludge landfill. Organic clays best meet this adsorption requirement, and their effectiveness increases as the pH of the leachate increases. Figure 3 indicates this effect in a general way. Precipitation is more important than cation exchange at a pH avove 7, and effective removal of heavy metals from solution can be accomplished by maintaining leachate at a high pH; however, as stated previously, a sludge landfill tends to decrease in pH with time.

Theoretical predictions of clay requirements for leachate treatment can be made based upon the predicted concentrations of heavy metals in landfill leachate, leachate pH, cation exchange capacity (CEC) of clay to be used, and the quantity of leachate which must be treated. R. A. Griffin, (1) lists minimum design thickness of kaolinite and montmorillonite for removal of lead from leachate, based upon experimental data. The applicability to actual design is qualified by pointing out the uncertainties of field conditions, and further caution is expressed concerning the possible changes in soils and surface waters brought about by changed environmental conditions. For example, a subsequent decrease in pH may release heavy metals previously adsorbed by the clay. In view of the complex nature of the soil-leachate interactions and the limited information with which the designer must work, it is prudent to be very conservative in design. Allowance should be made for effects of those many factors and interrelationships which are unknown or which cannot be controlled.

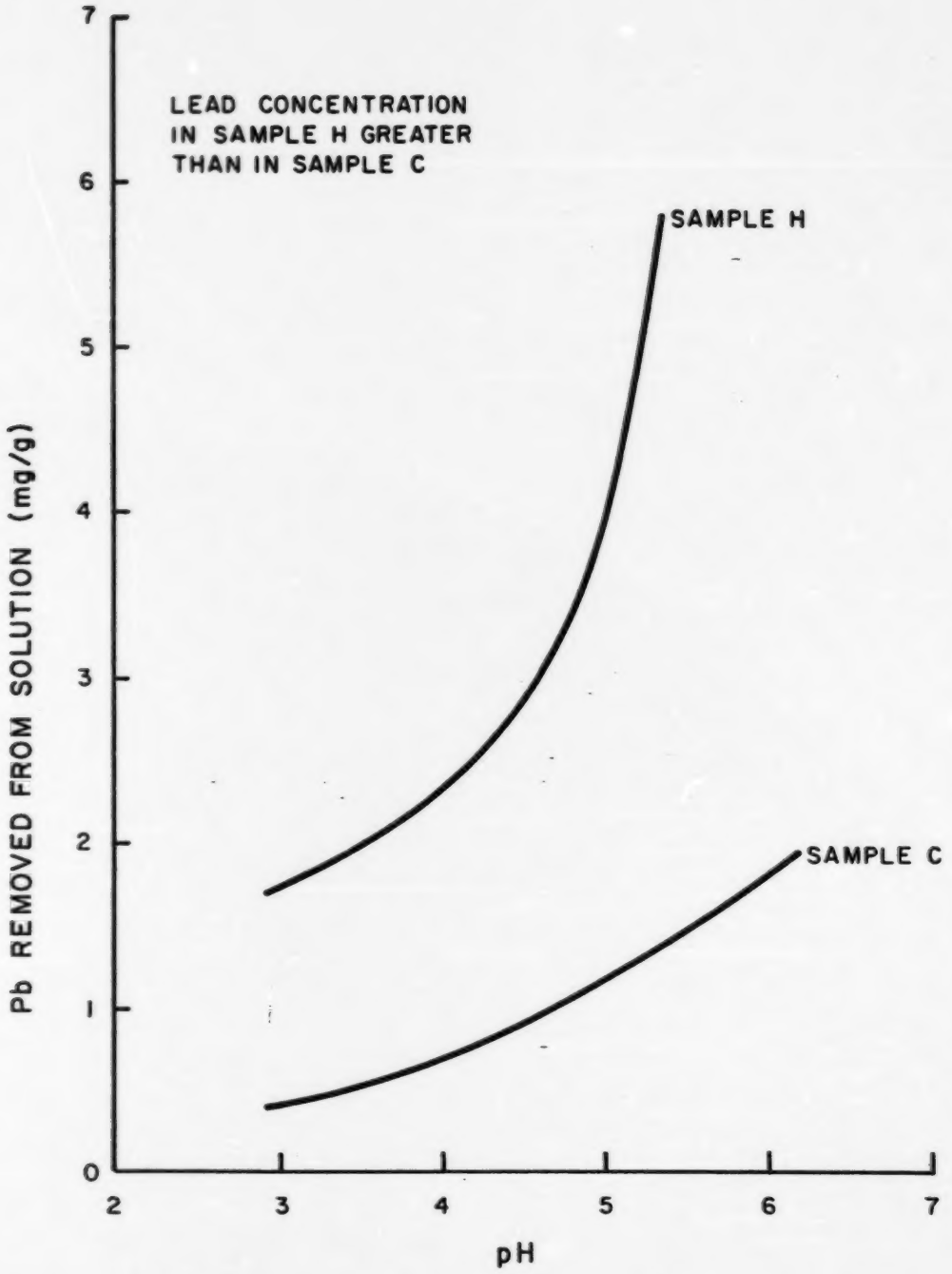
No attempt is made here to provide specific criteria for design of the soil base necessary between a given wastewater sludge and groundwater. However, a few general guidelines for design of a landfill base without leachate collection can be listed from the previous observations. The soil base refers to the soil layer between the sludge and the high groundwater elevation.

1. A conservative approach is to assume that leachate will be generated and a soil base is necessary for attenuation of pollutants.

2. Evaluation of the potential impact of leachate on groundwater and of how this relates to existing and potential groundwater use should be completed before proceeding with landfill design.

3. The soil base should contain sufficient fines to attenuate leachate pollutants, and organic clay should be included in the base soils to adsorb heavy metals.

4. The distance to groundwater should be as great as possible to provide an adequate treatment zone. An arbitrary minimum of four feet is suggested to allow for the many uncertainties inherent in landfill design. For a given sludge and soil, a greater depth of sludge requires a greater soil depth above groundwater.




SOURCE: R. A. GRIFFIN et al, ILLINOIS STATE GEOLOGICAL SURVEY

FIGURE 3

AMOUNT OF Pb REMOVED FROM DuPAGE LEACHATE BY MONTMORILLONITE AT 25° C

5. Use of a very impermeable base such as clay should be used only where there is no probability of breakout of leachate above ground.

6. A groundwater monitoring program should begin as soon as possible to establish background data on groundwater quality and to identify changes in groundwater quality as the landfill operation proceeds.

General Planning Notes

Included in the many other items requiring evaluation during the site selection process is the requirement for cover material and its availability on site. From one to two cubic yards of soil for cover and mixing is required for each cubic yard of vacuum filtered sludge to be landfilled. The specifications for the soil may vary greatly, but the quantity requirement is much the same. Soils are also required to separate the landfill base from groundwater, whether they contain an impermeable liner in a design with leachate collection, or they comprise the treatment layer for a landfill without a collection system. If on-site soils are not sufficient for base and cover requirements, the deficiency must be met by importing soils from appropriate off-site sources. Importation of soils from off site can be the most expensive item in the landfill operating budget.

Item 2 of the previously listed guidelines stresses the importance of groundwater evaluation to landfill design. In fact, such an evaluation should be made for each alternative design for each site investigated. Site comparisons can then include data on probable costs for a given level of environmental risk relating to impact on groundwater. The problem with this approach is that detailed analyses and extensive field investigations may be required for each site if suitable data are to be obtained for reasonable comparisons. For example, analysis of groundwater flow may require use of a sophisticated computer program and a number of borings to obtain input data for the program. Computer programs also can be used to predict impact of leachate on groundwater quality; however, budget limitations may limit the use of such programs to site design.

A minimum program for site design should include enough hydrogeologic data to establish general soils types and depths, depth to groundwater, and direction of groundwater flow. A groundwater monitoring program should be implemented as early as possible to establish background data before construction of the landfill starts. This may be important to the operating agency to establish conditions not caused by the landfill as well as indicating changes in groundwater quality caused by the landfill. Samples obviously should be tested for all constituents which may pose a problem or be questioned in the future. A minimum program might include tests for nitrates, TKN, COD, heavy metals, and conductivity, depending on landfill design and use of groundwater. Some state regulations indicate that three monitoring wells are the minimum required, one upgradient from the landfill and two on the down gradient side. In most situations several wells will be required, and there may be a need to obtain samples at various depths.

A groundwater monitoring program is not a substitute for proper design. This statement is not intended to discourage proper monitoring; it is intended to point out the potentially very high cost of correcting groundwater contamination from a landfill after substantial quantities of sludge have placed. The nature of landfill design and operation makes the conservative approach a prudent choice, and considering the possible consequences of failure to meet design objectives, this is probably also a cost effective approach.

## References


1. Griffin, R.A., R.R. Frost, A.K. An, G.D. Robinson, and N.F. Shimp. April, 1977. Attenuation of Pollutants in Municipal Landfill Leachate by Clay Minerals: Part 2 - Heavy-Metal Adsorption. Illinois State Geological Survey, Environmental Geology Notes Number 79.

2. Stone, Ralph, 1974. Disposal of Sewage Sludge into a Sanitary Landfill, Final Report SW-71d, U.S. Environmental Protection Agency.

3. Lofy, R.J., R.P. Stearns, K.V. LaConde. Implementing an Agricultural Sludge Utilization Program. Environmental Protection Agency Technology Transfer Design Seminar on Sludge Treatment and Disposal.